Vol. V. No. 1.

JOURNAL

OF

The Engineering Society

OF

THE LEHIGH UNIVERSITY.

ISSUED QUARTERLY.

NOVEMBER, 1889.

JOURNAL

OF

THE ENGINEERING SOCIETY.

ISSUED QUARTERLY.

Subscription, $1.00 per Year. Single Copies, 25 Cents.

Subscriptions, Communications, etc., should be addressed to the Business Manager, No. 57 Market Street, Bethlehem, Pa.

[*Entered at the Post Office at Bethlehem, Pa., for transmission through the mails at second-class rates.*]

CONTENTS:

DAILY TIMES PRINT,
BETHLEHEM, PA

JOURNAL

OF

THE ENGINEERING SOCIETY

OF

THE LEHIGH UNIVERSITY.

VOL. 5. NOVEMBER, 1889. NO. 1.

ABSTRACT OF PROCEEDINGS.

September 23, 1889.—President in the chair at 19.30 o'clock, eight members present. Treasurer report and accepted. All eligible members of the Junior class elected to membership, also Messrs. De Moyer, Van Cleve, and Potter. Messrs. Wilcox, Sherwood, and Flather, elected honorary members.

October 7, 1889.—President in the chair at 19.45 o'clock, twelve members present. Librarians report read and accepted. Mr. Neumeyer elected to membership. Mr. F. E. Fisher read an article on "Metallic Railroad Ties."

October 21, 1889.—President in the chair at 19.30 o'clock, fifteen members present. Prof. Klein delivered an address on "The Deformation of Materials," for which a vote of thanks was extended to him by the society. Mr. Litch made a few remarks on soft cores in rails. Mr. Landis also spoke for a few minutes. Mr. Kemmerling was elected Associate Editor.

FRED. E. FISHER, Sec'y.

THE LAW OF PROPORTIONAL RESISTANCES.

A CHAPTER IN THE MECHANICS OF DEFORMATION.

The deformation of materials arising in engineering practice may be classed under three heads:

(*a*) Elastic or temporary, deformations, within the elastic limit, (*b*) permanent deformations, beyond the elastic and within the break-

ing limit, and (*c*) deformations beyond the breaking limit, involving fracture of the material. Examples of the first kind are the tensile, compressive, shearing and twisting strains occurring in the members and pieces of well designed structures and machines; the second kind is represented by wire-drawing, rolling and forging, while blasting, pulverizing, planing, turning, milling and punching, illustrate the third class of deformations.

The theory of the first class of strains has been very fully developed, and it is now comparatively easy to compute the work and forces necessary to produce them in homogeneous material, when certain constants connected with the latter have been found experimentally.

But the same cannot be said of the second and third classes of deformations, for too little is yet known of the internal structure of the body and the action of its molecular forces. The forces and work necessary to produce these distortions and fractures have thus far not been found by computation, but by experience. After a number of deformations of the same general character have been successfully effected, an engineer by analyzing and comparing them, may estimate, approximately, the forces necessary to produce the same sort of deformation on a different and larger scale. But this requires engineering ability of a high order, and too often it has happened that such estimates have been both useless and costly.

As the matter cannot be approached by computation, and as experimenting on the actual scale is costly and uncertain, the question arises whether it is not possible to effect the desired deformation on a small scale, and with this experiment as a basis, compute the work and forces needed for a similar deformation on a much larger scale.

The idea is by no means a new one, and has been utilized now and then; but it has not often been tried, for no general law was known which connected small and large deformations. The builders of machinery and bridges long ago learned that to work a larger piece or to carry a larger load, it did not suffice to make an enlarged, geometrically similar, copy of the model of a machine or bridge.

Now, however, the idea is a practicable one, for a law has been discovered by Prof. Fred. Kick, which is true for all kinds of deformations, and enables the engineer to attack his problem in a systematic, and comparatively direct, way.

In what follows, we shall first state and illustrate this law, apply it to a great variety of deformations to see whether it agrees with known results, then seek to establish the law by stating the direct experimental evidence and theoretical considerations which sustain it, and finally enumerate the precautions which have to be observed in order to successfully use the law for engineering purposes. The arguments, illustrations and applications here given are mostly taken from Prof. Kick's own monograph.*

Before stating the law in Prof. Kick's concise words, I will state it a little more fully in my own words.

If two geometrically similar bodies of the same material have their forms changed in such a way that at every stage of deformation the bodies remain geometrically similar and the rapidity of deformation is the same in both, then will the work of deformation be proportional to the volumes or to the weights of these two bodies.

It should be noticed that this does not limit the character of the deformation; *one* of the bodies may be subjected to any change of form whatever, so that its final form is utterly unlike its initial, original, form. The limit set to deformation applies only to the second piece with which it is to be compared. In order that the work on the second piece may be fairly compared with that of the first, they must both, at every instant, undergo geometrically similar deformation. In other words the ratio of any two homologous dimensions, (the heights for instance), must be constant at every stage of the deformation.

Prof. Kick's statement of the law is as follows:

"The quantities of work necessary to produce *corresponding* changes of form in two geometrically similar bodies of the same material, are directly proportional to the volumes or weights of these bodies."

Here the term *corresponding* implies a great deal; it implies that the deformation progresses in such a way that the bodies are geometrically similar at every stage, that the forces or tools act similarly and that the deformation proceeds with approximately the same rapidity in each body.

* Das Gesetz der Proportionalen Widerstände; Leipzig, 1885. The law was first announced by Prof. Kick in Dingler's *Polyt. Journal* Vol. 234, pp, 257–345. 1879.

The analytical statement of this law is:—

$$W : W_1 :: V : V_1 :: G : G_1 :: 1 : r^3.$$

Here W, W_1 represent the works expended, V, V_1 the volumes, G, G_1 the quantities or weights, and r the ratio of two homologous, or corresponding, linear dimensions of the two bodies compared.

Now in many cases of deformation, it is not the work, but the pressures, which are directly measured, as in the case of the hydraulic press. It is therefore desirable that the law be cast into a more convenient shape. This can be easily done in the following way:

In an element of time dt there will be performed the quantities of work $d\,W$ and $d\,W_1$; in this infinitesimal interval we can consider the respective pressures P, P_1 as constant and acting through the corresponding distances ds, ds_1. As work is made up of the two factors, pressure, and distance through which pressure is exerted, we have

$$d\,W = P\,d\,s \text{ and } d\,W_1 = P_1\,d\,s_1.$$

As the two bodies are supposed to be geometrically similar to to each other at the beginning of the interval, and geometrically similar at the end of the interval, we have

$$d\,s : d\,s_1 = 1 : r$$

and for the same reason the law gives us

$$d\,W : d\,W_1 = P\,d\,s : P\,d\,s_1. = 1 : r^3.$$

Dividing the second of them by the first we get

$$P : P_1 = 1 : r^2 = F : F_1 = S : S_1$$

where F, F_1 are corresponding cross-sections, and S, S_1 the superficies or surfaces of the two bodies. The law can then be stated in this form:

"The pressures necessary to produce corresponding changes of form in two geometrically similar bodies of the same material are directly proportional to corresponding cross-sections or the surfaces of the pressed bodies."

In order that the law may be better understood we will apply it to two examples, using round numbers for simplicity's sake. In the first example the deformation is effected by a blow. A copper cylinder 1·4 in. high and 1·5 in. in diameter, and weighing 18 grains, (Troy), requires 40 ft. lbs. of hammer-work to reduce its height one-half. How much work would a copper cylinder 2½ in. high and 2 in. in diameter and weighing 18,000 grains, require to reduce its height one-half and to a shape similar to that finally reached by the small cylinder.

Using the first formula we have

$$W : 40 = r^3 : 1 = 10^3 : 1 = 1000 : 1$$

$$W = 40{,}000 \text{ ft. lbs.}$$

The same result is of course obtained if we substitute the weights:

$$W : 40 :: 18{,}000 : 18.$$

As weights are more easily and exactly found than linear dimensions, the latter method is the one which will be most used.

As the deformation is supposed to take place with approximately the same rapidity, the height through which the hammer falls in two cases is assumed to be the same and equal, say, to 4 ft. Then the weight of the hammer in the first case would be 10 lbs., and in the second case 10,000 lbs. The author states, however, as the result of his experiments, that small differences of velocity have little influence on the result; for instance, it makes but little difference with the deformation whether the hammer-work W is produced by 10,000 lbs. falling 4 ft., or 5,000 lbs. falling 8 ft.

Of greater importance than the velocity are the inequalities of the material. Larger pieces that have not been thoroughly worked may have blow-holes, pores, or empty spaces, while smaller, thoroughly worked pieces, are free from them. For instance, if the small copper cylinder mentioned in the above example were made out of copper wire, and the large one out of a superficially forged copper bar, they could not be regarded as the same material. The proper way would be to cut the small piece out of the large one, after having first taken pains to render the large piece as homogeneous as possible.

The second example which we will consider, illustrates the second form into which the law has been cast. Here the change of form is due to pressure instead of to a blow.

A copper cylinder 0.7 in. high and also 0.7 in. in diameter was reduced in height by a gradually increasing pressure. The relation between the pressures and the heights is shown by the following figure:

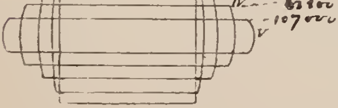


Fig. 1.

For practical purposes it usually suffices to know the pressure corresponding to a particular deformation. In this case we wish to know the pressure corresponding to deformation V (Fig 1) when the cylinder is 5 times as large as that experimented upon,

that is, has an initial height and diameter equal to 3 5 in. This maximum pressure is easily found from the second statement of the law.

$$107{,}000 : P_1 = 1 : r_2 = 1 : 25$$
$$P_1 = 2{,}675{,}000 \text{ lbs.}$$

We could have used weights instead of pressures, the relation being $\frac{1}{r_2} = \left(\frac{G_1}{G}\right)^{2/3}$ but it would not be so convenient for calculation.

The law tested by application to well known deformations,

Blasting. — The first application will be to blasting, and we shall deduce from the law of proportional resistances a very old axiom in the technology of explosives, namely: "Two normal charges of the explosive are to each other as the volumes of the cones they throw out." In the figure is sketched one case, showing the blast hole, the tamping, the powder chamber and the volume blown out; the ratio of the diameter of the blast holes is the same as that of the lines of least resistance (or depths) MC, $M_1\,C_1$; the corresponding linear dimensions of the two powder chambers, bear to each other this same ratio of the depths, $M\,C$ to $M_1\,C_1$; in other words, we have in the powder chambers two geometrically similar volumes V and V_1. We assume that the progress of deformation during the successive stages of the blast (if this expression is allowable when the action is so prompt) is similar in the two cases, and we then can apply the law, which is, expressed analytically,

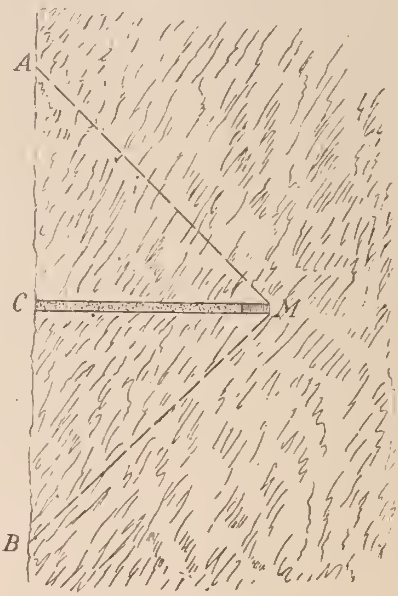


Fig. 2.

$$P : P_1 = 1 : r^2 = M\,C^2 : M_1C_1^{\,2},$$
$$\text{but} \quad P = pf \quad \text{and} \quad P_1 = p_1 f_1$$

where p and p_1 are the specific pressures generated by the blast in the chambers, and f and f_1 the area of the surface pressed upon. From the similarity of the chambers we have,

$$f : f_1 = 1 : r^2,$$

substituting in the first proportion

$$P : P_1 = f : f_1$$

$$pf : p_1 f_1 = f : f_1$$

$$\text{or} \qquad p = p_1$$

that is, the specific pressures of the gases produced by the explosion must be equal. Now the combined law of Mariotte and Gay Lussac gives us for gases the relations

$$\frac{V}{C} = \frac{R\,T}{p} \quad \text{and} \quad \frac{V_1}{C_1} = \frac{RT_1}{p_1}$$

when R is a constant depending on the kind of the explosive, and C, C_1, the weights of the respective charges of powder.

If we suppose complete gasification of each of the charges to take place and the same temperature to be obtained in both cases, then we have

$$\frac{V}{C} = \frac{V_1}{C_1}, \text{ and } C : C_1 = V : V_1 = 1 : r^3 = \overline{MC^3} : \overline{M_1 C_1^3},$$

but the volumes V' and V_1' of the two blown out ones bear the same ratio, $1 : r^3$, to each other, and we get finally

$$C : C_1 :: V' : V_1',$$

which is the analytical statement of the axiom mentioned at the beginning of this problem.

Callon, the great mining engineer, gives the same rule, but says that while theoretically there is no difference in economy between heavy and light charges, practically, heavy charges are the most economical. But this does not militate against the law. The apparent discrepancy can be explained by the lower temperature developed by small charges on account of the proportionately larger cooling surface of the smaller chamber. Moreover large blast cones will be apt to meet a greater percentage of weak spots in the rock and thus permit a larger volume to be loosened for the same charge.

Bursting and Collapsing Strains.—When two closed vessels, geometrically similar are subjected to inner or outer pressure, the law prescribes that the total pressures P, P_1 shall have the relation

$$P : P_1 = 1 : r^2.$$

But the surfaces S, S_1 pressed upon are similar and hence

$$S : S_1 = 1 : r^2,$$

therefore, $$p = \frac{P}{S} = \frac{P_1}{S_1} = p_1;$$

that is the specific pressures within or without the two similar vessels must be the same in order that bursting or collapsing may take place in each.

Let us see if this agrees with well-established formulæ for boiler shells; here

$$t = \frac{pD}{f} \quad \text{and} \quad t_1 = \frac{p_1 D_1}{f_1},$$

where f, f_1 is the ultimate strength, t is the thickness of the shell and D its diameter. The formula does not contain the length l of shell as this is known to have little influence on the strength; we may therefore disregard, with respect to the length l, the condition that all the dimensions of the two boilers must be similar. Comparing the two cases, we find

$$\frac{t}{t_1} = \frac{p}{f}\frac{f_1}{p_1}\frac{D}{D_1} = \frac{D}{D_1},$$

because $$\frac{p}{p_1} = 1, \quad \text{and} \quad \frac{f_1}{f} = 1.$$

The thicknesses are therefore proportional to the diameter as the law requires.

Now let us apply the law to the fire flues of boilers, which are subjected to collapsing pressures. Here the length l is known to influence the resistance to collapsing, consequently we find it in the empirical formulæ,

$$p = \frac{9{,}672{,}000\ t^{2.19}}{l\ D},$$

which was deduced by Fairbairn directly from his experiments.

Comparing two flues, substituting $p = p_1$ as above and assuming that

$$l : l_1 = D : D_1 = 1 : r, \quad \text{or} \quad l_1 D_1 = r^2 l D,$$

then if the law holds, the remaining dimension t_1 should equal $r \times t$. Now substituting in Fairbairn's formula and dividing and transposing we get,

$$\left(\frac{t_1}{t}\right)^{2.19} = \frac{p_1 l_1 D_1}{p\, l\, D} = \frac{l_1 D_1}{l\, D} = r^2,$$

that is $t_1 = r^{0.91} t$ instead of $r t$ as the law requires. Considering that the experiments were not carried out with geometrically similar pieees, this must be regarded as a satisfactory agreement.

Metal and Wood-working Machinery, Planing, Turning, etc.—According to Dr. Hartig's experiments,* the *net* work necessary to bend plates or bars, to cut hot iron or wood with a circular saw, to plane, turn, drill or shape cast iron, wrought iron and steel, to cut screws or tap nuts, and to drill wood, depends either upon the volume or weight of the material removed, provided the two bodies compared and their chips are of the same material and geometrically similar. Although Dr. Hartig does not seem to have recognized the law of proportional resistances, it is directly deducible from the empirical formulæ set up by him for the kinds of work above mentioned. In the case of shearing machines, the formula given includes the work of running the machine empty, but other experiments adduced by Prof. Kick show that for the *net* work of both punching and shearing machines, when the tools are properly set and act similarly, the law is followed. The cases of shearing and punching are also of special interest, because in large work and other things equal, the length and breadth of the plate have little influence on the shearing and punching force. Hence these forces are to each other as the squares of the only homologous dimensions, the thicknesses. In the case of punching the ratio of diameter of punch to thickness of plate must be the same in the two cases.

Prof. Kick refers to J. Thime's work on planing as the most thorough one, and as it illustrates what is meant by geometric similarity of deformation, we will reproduce it. Thime's formula** for the force exerted by the tool is

$$P = c \frac{\sin \alpha}{\sin \beta_1 \sin \beta} b h,$$

when c is a constant for the same material and β is, $180° - (\alpha + \beta_1)$; the meaning of α and β_1 is shown by the sketch in Fig. 3. For similar tools and similar chips of the same material, we have

$$P : P_1 = b h : b_1 h_1,$$

---

* See D. K. Clark's *Manual for Mechanical Engineers*, pp. 951–955; also *Engineering* for October and December, 1874.

** Memoire sur le rabotage des métaux, St. Petersburg, 1877.

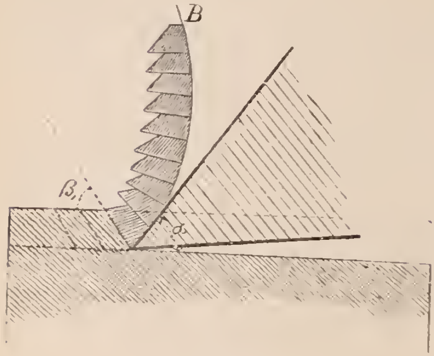


Fig. 3.

b being the width and h the thickness of the strip of metal removed by the tool.

It is evident that in planing, the similarity of the whole bodies operated upon is of no consequence, simply the deformations, that is, the sections removed and their resulting chips, must be similar.

There is difficulty in producing similar chips even with similar tools and work-pieces, on account of the spring of the tools. It is important to appreciate this point, for, the instant that this similarity does not exist the proportionality of work and chip-weight ceases.

An interesting deduction from this law is, "To produce a given weight of geometrically similar chips, there is required a determinate amount of work, which is independent of the fineness or the coarseness of the chips."

Forging under Hammers.—So far as the writer is aware there exist no experiments on a large scale, suitable for testing the law in this important particular. Prof. Kick's experiments were confined I believe, to the cold-forging of the common metals and were on a very small scale. But as they were very carefully made and showed an excellent agreement with the law, there is a strong presumption that the latter is applicable to larger work. Thus, if a piece has been worked under a hammer of weight Q and fall H, then a geometrically similar piece will be similarly deformed when subjected to blows of similar intensity. According to the law

$$Q\,H : Q_1\,H_1 = 1 : r_3,$$

where r is the ratio of the corresponding linear dimensions of the work-pieces and not of the tools (or hammers). If we made the mistake to increase the dimensions of the whole hammers in this ratio r, we would get

$$Q : Q_1 = 1 : r_3,$$
$$H : H_1 = 1 : r,$$
and $$Q\,H : Q_1 H_1 = 1 : r_4,$$

and the enlarged hammer would give too intense blows and would not be accompanied by a similar deformation.

If we suppose the power of the hammer is increased by steam acting on the top of the hammer-pistons during their descent, imparting the additional quantities of work W' and W_1' respectively, we have

$$(Q\,H + W') : (Q_1\,H_1 + W_1') = 1 : r^3.$$

Rolling of Iron and Steel.— Experiments by a commission of German Metallurgists* on the power needed to roll iron and steel, were, unfortunately for our comparisons, not conducted in such a way as to contain geometrically similar pieces. The law can not therefore be tested directly. Indirectly, however, the results of the experiments are confirmatory, for E. Blass, an engineer of the commission, on the basis of these experiments, established formulae which agree with the law.

We will here add a few deductions from this law by Prof. Kick.

"Equal weights of bars or plates of the same material and of geometrically similar cross-sections, when rolled by geometrically similar rolls, require the same quantity of work when the percentage of reduction is the same."

"The resistance experienced by geometrically similar work-pieces in the direction of their motion through the rolls, is proportional to the cross section of these pieces, provided, the rolls are also geometrically similar and the percentages of reduction are the same."

"When geometrically similar conditions exist everywhere and the material of the work-pieces is the same, the specific pressures at corresponding elements of the surfaces of the rolls will be the same."

Crushing, Stamping and Pulverizing.— Experiment shows that the same work is required whether a body is demolished by hitting another or by being hit by it. This is not an *a priori* deduction, but an experimental result and furnishes the means of computing the requisite velocity of blow for disintegrators. It is only necessary to drop a body from a height capable of breaking it and find the velocity corresponding to this height.

The direct experimental evidence in favor of the law.

Prof. Kick has given eight years of experimental work to prove the law of proportional resistances. When his prelimi-

* "Stahl und Eisen," No. 2, p. 57, 1881, also No. 7, 1882.

nary experiments and other theoretical considerations had shown him the probable truth of the law, he conducted his subsequent experiments, so that the pieces and deformations were, as nearly as possible, geometrically similar. In other respects the experiments were both numerous and varied. Many different materials were used; fresh bread, sand, porcelain clay, cement, glass, stones and metals; also many different forms, such as, plates, prisms, frustums, cylinders and spheres; the modes of applying the forces were also various; bodies were compressed by steady pressure between parallel plates, others were squeezed between rolls, some were sheared and punched, some were broken up by one or more hammer blows or by being dropped from a sufficient height and one was burst by internal water-pressure. The experiments adduced were not simply those made by the author, but others also were used whenever they contained examples that fulfilled the fundamental condition of geometric similarity. In the great majority of cases, there was an excellent agreement with the law, and when these were apparent failures, the author succeeded in explaining them by most plausible reasons. It is certainly desirable that the law should be confirmed for metal-working, by experiments on a large scale and with geometrically similar pieces and deformations. There is undoubtedly force in Prof. Kick's contention, that more exact work can be done with small pieces, as in chemical investigations; but before engineers will apply the law with confidence, it must be confirmed by work done on the large scale common to engineering operations.

Theoretical considerations sustaining the law.

The question arises whether this law has a rational basis and whether it is not possible to establish it by *a priori* reasoning. As deformation implies a shifting of the particles of the body relatively to each other, we see at once that a trustworthy solution of this problem involves exact knowledge of the internal structure of bodies and of the action of the molecular forces. This we do not possess as yet and the best that can be done in this line is to make as plausible assumptions as possible. We suppose as before, two geometrically similar bodies of the same material, to be simultaneously so deformed, that at every stage of the deformation they remain geometrically similar and their corresponding linear dimensions preserve at every instant the same ratio *r* which they originally possessed.

Let us, for an infinitely small interval of time, compare the behavior of a small group of particles $d\,V$ in one body with that of a similar and similarly situated group $d\,V_1$ in the other body. Then by our hypothesis we have

$$d\,V : d\,V_1 = V : V_1 = 1 : r^3.$$

Now each little mass $d\,V$, when it shifts its position relatively to its neighbors, must overcome the resistance offered by these neighbors. These act on the surface $d\,S$ of the little mass with a specific pressure p, offering a total resistance pdS to its shifting. We now make an assumption on which the validity of the whole reasoning must rest, namely, we assume that the little mass dV_1 of the second body must overcome the *self same specific resistance* p as its similar and similarly situated fellow dV in the first body. This will make $p\,d\,S_1$ the total resistance to the shifting of $d\,V_1$ at this instant. Hence the elementary quantities of work will be respectively:

$$d\,W = (p\,d\,S)\,ds,$$

and $$d\,W_1 = (p\,d\,S_1)\,ds_1,$$

the last differential factor in each expression representing the amount of the shifting. From the similarity of the two bodies and their parts, we have

$$d\,S_1 = r^2\,d\,S$$

and $$ds_1 = r\,ds;$$

substituting above, we have

$$d\,W : d\,W_1 = (p\,d\,S)\,ds : r^3\,pdS\,ds = 1 : r^3.$$

As this relation holds for every pair of little masses that are similar and similarly situated and as the number of these masses is the same for each of the bodies, the total work expended on two bodies will bear to each other the ratio $1 : r^3$ or $V : V_1$.

Of course all depends on the validity of the underlying assumption, that similarly situated particles, during corresponding and simultaneous displacements relatively to the neighboring particles, have to overcome the same resistance per unit of area. As this assumption does not forbid the specific resistance to vary at different stages of the deformation, we have here as simple a supposition as can be made, and for that very reason a probable one. But it is rendered a likely one by other considerations: for instance, as the deformations are similar at every instant, the simultaneous variations of the elementary volumes are all in the same direction, that is traverse parallel paths, which in turn pre-

supposes a perfectly like play of all the inner and outer forces. Even if we do not know the distribution of pressure within the body, we are endorsed by experiment when we say that similar deformation can only occur when the *outer* forces act in the same manner, and when the *specific pressure is the same on corresponding superficial elements*. If this is so, similar resolution of the forces requires that the forces be propagated through the body in the same way, and then will the active specific stress at any point m in one body be equal to that at any corresponding point m_1 in the other; but if the active stresses are alike at corresponding points, they can overcome like specific resistances at these points. This would seem to justify the assumption above made, and thus prove the law as far as it is possible to prove it without a more intimate knowledge of the internal structure of bodies.

The law also receives support from the fact that it is known to be true for one important and well-known class of deformations, those, namely, which take place within the elastic limit. In the first place it has been proved (see Weisbach-Hermann's *Mechanics of Engineering*, Vols. I and III). that bars subjected to shocks which do not strain them beyond the elastic limit, to tensile, flexile or twisting stress, absorb work proportionately to their volumes, which is in accordance with the law first formulated by Prof. Kick. It will be noticed that the law only extends to the breaking limit what is already known to exist up to the elastic limit.

Again, the work done within the elastic limit in bending or twisting springs by a gradually increasing force follows this law when the springs compared are geometrically similar bodies. For the many different forms of springs for which this is true see formulas given in Weisbach's *Mechanics*, Vol. I, last edition, also the Hütte's "*Taschenbuch*."

Prof. F. Steiner has shown that for deformations within the elastic limit the law is followed by framed structures whose members are subjected to longitudinal stresses, also by a continuous beam when acted upon by any number of con-plane forces, acting in one of the principal planes of the body. He has moreover shown that the law is obeyed in liquids and gases, but as the deformation of the latter is not of technical importance, we will omit it and reproduce only the demonstrations given for any framed structure and for any continuous, solid, beam.

See Dingler's *Polytechnisches Journal*. Band 251; p. 259; 1884.

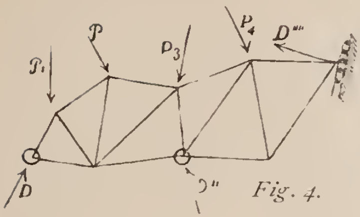


Fig. 4.

Fig 4 represents any system of elastic bars subjected to the action of the external forces P_1, P_2, etc., which during the deformation respectively traverse the paths p_1, p_2, etc. S_1, S_2 .... are the stresses felt in the bars of length $l_1, l_2, \ldots$, cross-section $F_1, F_2 \ldots$, modulus of elasticity $E_1, E_2 \ldots$ respectively; then will the work of deformation A by the exterior forces P equal the inner work performed by the forces S; that is

$$\mathrm{A} = \frac{P_1 \; p_1}{2} + \frac{P_2 \; p_2}{2} \ldots = \frac{S_1^2 \; l'}{2 \, E_1 \, F_1} + \frac{S_2^2 \; l_2}{2 \, E_2 \, F_2} + \ldots \ldots \quad (1)$$

$$\text{or more briefly } A = \Sigma \frac{P p}{2} = \Sigma \frac{S^2 \, l}{2 \, E \, F} \ldots \ldots \quad (2)$$

The forces D', D'', D''', etc., at the supports perform no work when the latter are rigid. Now comparing any two geometrically similar systems I and I' of the same material (using accents on the symbols relating to second system) and assuming that all homogeneous linear dimensions in the second system are r times larger than those of the first, and also that the corresponding deformations bear to each other the same ratio r, we have:

$$\frac{\triangle \, l'}{\triangle \, l} = \frac{S' l'}{E F'} : \frac{S \, l}{E F} = r \text{ and } F' : F = r^2 : 1$$

hence,

$$S' = r^2 \, S.$$

For the deformation of the second system I', we now have:

$$A' = \Sigma \frac{S'^2 \; l'}{2 \, E \, F'} = r^3 \, \Sigma \frac{S^2 \; l}{2 \, E \, F} = r^3 \, A \quad (3)$$

which is in accordance with the law of proportional resistances.

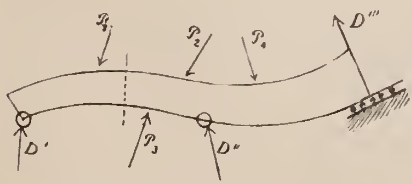


Fig. 5.

In an analogous manner we proceed with the continuous, solid, beam shown in Fig. 5, where the forces all act in one of the planes of the beam. Let I stand for the moment of inertia of the beam's cross-section F, M its bending moment, and N the axial force in any normal section, then the work of deformation is:

$$A = \Sigma \frac{P p}{2} = \int \frac{M^2 \, d \, s}{2 \, E \, I} + \int \frac{N^2 \, d \, s}{2 \, E \, I} \quad (4)$$

If we compare any two geometrically similiar beams I and I'

and suppose them to experience similiar deformations, then will

$$\frac{d\,s'}{d\,s} = r = \frac{N'\,d\,s'}{E\,F'} : \frac{N\,d\,s}{E\,F}$$

(here $d\,s$ and $d\,s'$ take the place of l and l' of the proceeding demonstrations); from this and because $F' : F = r^2 : 1$, we have $N' = r^2\,N$. In like manner for any angular motion $d\,\phi$ of two contiguous cross-sections, we find

$$\frac{d\,\phi}{d\,s'} : \frac{d\,\phi}{d\,s} = 1 : r = \frac{M'}{E\,I'} : \frac{M}{E\,I},$$

and since $I' : I = r^4 : 1$, we get $M' = r^3\,M$. Substituting, the deformation work for the second system becomes:

$$A' = \int \frac{M'^2\,d\,s'}{2\,E\,I'} + \int \frac{N'^2\,d\,s'}{2\,E\,F'} = r^3 \int \frac{M^2\,d\,s}{2\,E\,I} + r^3 \int \frac{N^2 d\,s}{2\,E\,F} = r^3\,A$$

which is in entire accordance with the law in question.

If we let k represent the specific pressure in any member of the framed structure, or the specific pressure in any cross-section of the solid beam and on any elementary area at the distance c from the neutral axis, we will have, since $S' = r^2\,S$, for the framed structure:

$$k = \frac{S}{F} \quad \text{and} \quad k' = \frac{S'}{F'} = \frac{S}{F} = k.$$

For the continuous solid beam:

$$k = \frac{N}{F} + \frac{Mc}{I} \quad \text{and} \quad k' = \frac{N'}{F'} + \frac{M'\,c'}{I'} = \frac{N}{F} + \frac{Mc}{I} = k;$$

that is, *the specific pressures at homologous points of two similar systems are the same.*

Since $A = \Sigma \frac{Pp}{2}$ and $A' = r^3\,A = \frac{\Sigma P'p'}{2}$ and $p' = r\,p$

we can say that, *corresponding, deforming, external forces are proportional to the squares of homologous lines of the similar bodies.*

This, however, does not apply to the *weights* of the structural pieces themselves, because these vary as their volumes, i.e., as the cubes of the homologous dimensions.

Conditions and precautions in experimenting.

In general the law calls for an initial similarity of form; but this is not always an essential condition. Thus in planing it is of no, or very little, consequence whether the small sample to be operated upon is at any time geometrically similar to the larger body for which we wish to ascertain the work and the forces; here the essential point is, that similar strips of metal be changed into geometrically similar chips. There are other cases, such as

shearing and punching, when the length and breadth have little influence on the result and when geometric similarity of all the homologous dimensions is not a necessary condition. Here the work is proportional to the cube of the most important homologous dimension, the thickness. Finally there is the case of frictional work, for which we consider only the geometrically similar *surfaces* at which the friction is overcome. If we neglect the influence of the bodies' own weight in producing friction, no error would arise, even in this case, in comparing geometrically similar *bodies*.

The character of the deformation must be similar, should be performed in equal times with similar tools, acting with the same intensity on similar parts of the surface. In the case of metals and woods, it is not sufficient to remove geometrically similar strips of the original bodies, it is also necessary that the chips or shavings produced should be geometrically similar. This means that the cutting forces must attack in the same way; that is, the tools must be ground to the same angles and must spring in the same way. In order that the forces may act with the same intensity the *specific pressure exerted by the tool at corresponding stages of the deformation must be the same*. This important consideration has already been brought out in the application to blasting, collapsing and rolling, but its general character was most distinctly enumerated in the theoretical development of the law. Experiments on cold forging under the hammer showed the same deformation when the energy stored in the hammer was the same, and this even when the velocity of the hammer was four times greater in one case than in another. The variations of velocity due to the different falls of the ordinary forging hammers is therefore probably not great enough to influence the character of, or the power needed for, the deformation. This is probably due to the specific pressures exerted by the hammers being the same. On the other hand the energy stored in the striking hammer has considerable influence on the work of deformation. A few powerful blows (that is those in which the striking hammer contains a great deal of stored up energy,) can produce a given deformation with considerably less total work than a greater number of weaker blows.

It can readily be shown that three conditions of similar deformations with equal velocities and in equal times, are not compatible when the pieces compared are of unequal size. For let

ds and ds_1 represent any two elementary and similar, but unequal displacements or deformations, then will

$$\frac{ds}{dt} : \frac{ds_1}{dt} = v : v_1 = ds : ds_1 .$$

As experiment has already shown that the velocity may vary within quite a wide range (not yet known, but a good deal less than that which corresponds to shock on one hand and pressure on the other) we may say that the similar deformations in the pieces to be compared should occur in equal times. We may illustrate by taking a plastic mass such as lead. If we subject a lead cylinder to, say 1100 pounds pressure per square inch in the direction of its axis, the deformation will continue for days, in fact, the metal will not come to rest but will continue to flow. If it were desired to effect a given deformation more quickly, a greater pressure than 1100 pounds per square inch would be found necessary. So that to fairly compare the forces necessary to produce the same stage of deformation in two unequal but similar pieces of lead, we must know that they have both been subject to the same specific pressure for the same time. It is probable that the plastic masses, such as very hot iron, behave in the same way under stress.

Prof. Kick lays the greatest emphasis upon the material being *exactly alike in all its physical characteristics.* He says, for instance, that two cylinders of copper are not comparable, of which the small one is made of copper wire and the large one is taken from a great piece of superficially forged copper bar. When turned up into test specimens the two look exactly alike while in reality they are very different. He recommends the experimenter to get (or better still, to himself prepare) a large mass of the homogeneous material, and cut (by sawing or turning) both the large and the small test-specimens from it; the hammer is only to be used, when the piece has already been thoroughly worked under the hammer; even then the subsequent hammering should take place at red heat and after that the piece should be annealed. If the preparation involves melting, then after casting the top should be again heated and the mass allowed to cool slowly, from below upwards. From this it will be seen while it is no easy matter to obtain like materials when cold, that it will be still more difficult to get them in like physical condition as to density, plasticity, and temperature, when they are to be worked or deformed while hot. Nevertheless, difficult as

it may be, they must be nearly alike physically, if the results obtained by working on a small scale are to be safely transferred to the proposed large scale.

Prof. Kick further emphasized the importance of likeness of the material by performing experiments upon geometrically similar bodies of *different* materials and although they were subjected to deformations, he found not only that the law of proportional resistances was not followed, but he could not ascertain any relation between them.

There is a distinction between the deformation effected by live loads (or external forces) and that effected by dead loads (that is by the structure's or body's own weight). In the former case the works of deformation in any two geometrically similar structures or bodies obey the law and are proportional to the cubes of any two homologous linear dimensions. But the work of deformation developed by the structure's or body's own weight varies as the fourth power of any two homologous dimensions, if we suppose the bodies to be geometrically similar and their deformations also similar. Because the bodies are similar their weights will be as their volumes: *i. e.*, as the cubes of their homologous dimensions; the deformations being assumed to be in the same ratio, the products of the two factors, or the works, will be as the fourth power. Another way of stating the same thing, is that the corresponding external forces in the first case vary as the squares of the homologous dimensions, while above we saw that the corresponding dead weights varied as the cubes of these dimensions. Consequently in comparing the deformations and forces of a bridge model with those of the geometrically similar and larger structure we must bear this in mind. Likewise in applying the law to friction problems, we must remember, that the friction forces developed by the weight of the two bodies is not as the squares but as the cubes of any two similarly situated dimensions. The frictional resistances developed by forces external to the two bodies do however obey the law and are therefore as the squares. Also when treating of forging under hammers we called attention to the fact, that a geometrically enlarged copy of the smaller hammer would give a too intense blow for its hammer weight and would increase as the cubes instead of the squares of the ratio of enlargement.

As the experimental work is conducted on a small scale it is important that all measurements of deformation, dimension, force

or work should be as exact as possible. In pulverizing processes, for instance, care should be taken, by gradually increasing the blow, to find the *minimum* work necessary to break up the material. In experimenting with machine-tools care should be taken to ascertain and subtract all frictional influences so that the remaining work may represent only the work actually expended in performing deformation. In shearing machines for example, the tendency of the tool-slide to bind in its guides greatly increases the work and must be eliminated before the law can be applied. In the ascertaining of the actual work of deformation under hammers there is also a special difficulty in that the anvil absorbs a large percentage of the work contained in the falling hammer. To overcome this, the blows have been communicated to the workpiece by a ballistic pendulum and the work imparted to the suspended anvil, noted. But inasmuch as the two anvils are used under very different conditions, the diffiulty cannot be said to have been completely overcome.

Prof. Kick is particular to warn experimenters not to trust to the average of numerous, but carelessly conducted experiments, for accurate results, for in this kind of work it is extremely improbable that the errors will balance each other.

As a check on the accuracy of the experimental work, we would suggest that the similar experiments be performed upon two, or even more, different scales; then if the results are all in accordance with the law, there will be strong reason to believe that the experimenter's results are accurate and that when the work is carried out on full scale, the computed work and force will be found sufficient to accomplish the desired deformation.

J. F. Klein.

IRON RAILROAD TIES.

There is expended yearly in the United States over $6,000,000 for ties, which in the East consist mainly of chestnut and oak, and in the West and South of oak, cherry, locust, maple, and ash. To supply this demand 250,000 acres of woodland are annually needed, yielding 15,000,000 ties which cost the railroad companies 35 to 60 cents apiece. When we take into consideration the rapid destruction of our forests through this and other causes, and the consequent rise in the cost of timber, it becomes evident that at a not very distant date wooden ties for railroads

will have to be superceded even in this country. The life of a wooden tie depends upon

(*a*) the climate,

(*b*) the ballast whether well drained or not,

(*c*) the impact of passing trains which cut and abrade the wood.

The effect of a damp tropical climate is marvellous. In Mexico, creosoted hard oak ties rot and perish in 3 or 4 years even when not attacked by insects, and only the hardest and heaviest native woods will last for a reasonable period.

A damp, ill drained road bed will require renewing of the ties twice as often as a dry one. To resist abrasion hard wood is necessary, therefore white oak is perhaps the best. Redwood and cedar are used considerably in the extreme West, but they have this objection of being brittle and fail in 6 or 7 years by crushing and not by decay.

Originally rails were laid on blocks of stone which formed an extremely unyielding roadbed and as the rolling stock became heavier, cracked and broke. Sandstone yielded the most favorable results and as late as 1870 there were a number of German roads still using stone sleepers.

In parts of Siberia where it is difficult to obtain wood, asphalt ties have been used with considerable success; and lately Mr. Siemens has manufactured glass ties which behaved well when tested for their breaking strength, but the use of which up to date has been so limited that but few practical data concerning their value exist.

In Europe wooden ties are gradually being replaced by iron ones, for there the cost of either kind is about the same. In the tropics the use of wood is out of the question. Thus, although the manufacture of metal ties can hardly be said to have passed the experimental era, yet we have the results of the trial of many systems and shapes by which to be guided in the future.

As early as 1836–37 Mr. J. Reynolds endeavored to construct a roadway entirely of iron. His rails were of cast iron and of such shape as to support themselves on the ground. Experiments were begun in Belgium and France in 1844–46. However, the first valuable construction was the system of Mr. Greave which first came into use on the Lancashire and Yorkshire R. R. in 1847 and has since been used in Egypt, Algeria and India with excellent results, especially where the ballast is sand. It consists of cast iron shells, segments of a hollow sphere of considerable

radius, on the crown of which, forming part of the shell, is cast a channel into which the rails are slipped and fastened with wooden plugs. The shells are connected by iron bars and are about 21.5 inches in diameter, 7 inches high, ½ inch thick, and weigh 80 pounds. Seven pairs are placed under a 20 foot rail. These supports form a stable road bed, being well imbedded in the ballast, and seldom break. Under heavy traffic, unless they are increased in size, unequal sinkings occur and with pebble ballast continual tamping is necessary, to facilitate which the rails were at first made with holes supplied with stoppers. In clayey soils water entered in this way, forming iron oxide, which, on combining with the clay, formed a solid mass and caused the early destruction of the shell.

Griffin improved this system by making the shell larger, elliptical, and corrugated, while the rail was sunk in, instead of resting on the crown. Under a 21 foot rail 5 pairs of such shells are used. These supports give a full stability to the road, are not easily broken, and are laid and handled with facility; they can be used in clay soils, as is proven by their general use on the Pampas of the La Plata, Argentine Republic and in the whole La Plata region.

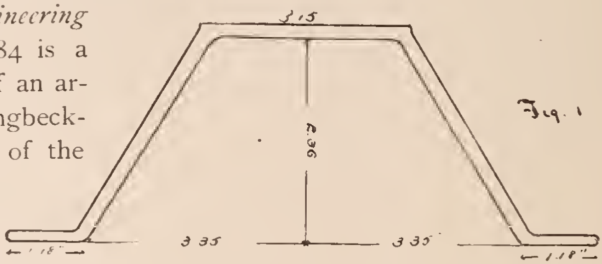


Fig. 1

In the *Engineering News* of 1884 is a translation of an article by M. Jungbecker, inspector of the Bergisch and Markisch R. R., giving the development of the iron *cross* ties as used upon that road. In 1867, 664 ties (figs. 1 and 2) were laid two feet apart. They soon cracked and the

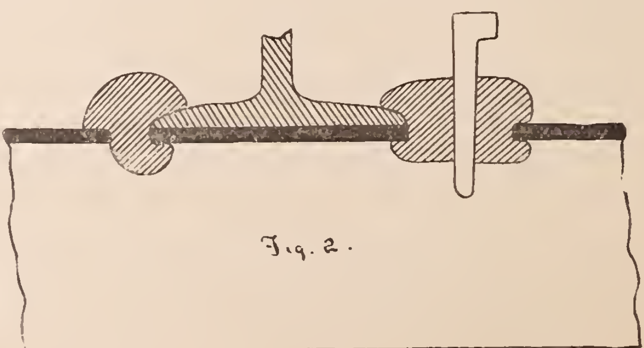


Fig. 2.

matter was abandoned until 1874 when 25,000 of the same general shape but with thickened upper plates were put in. These also cracked, but not to a great extent, and it was attempted to reinforce them by riveting on short tee irons transversely but without effect. A careful examination of the ballast showed a tendency for it to leave the under side of the tie. As a remedy the two small horizontal flanges were removed and vertical ones substituted, which confined the ballast, facilitated tamping, and prevented creeping. The form (fig. 3) was finally adopted as standard in 1879. Mild steel (fluss-

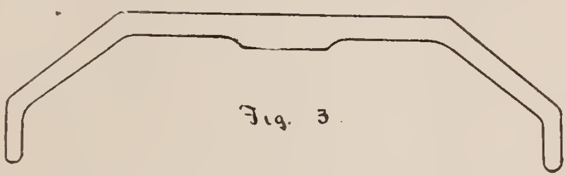


Fig. 3.

eisen) is the material used, the requirements being a tensile strength of 60,000 pounds an elongation of 15%, the ties being capable of being bent until the flanges meet without crippling the edges, and with a radius at the fold of 3 inches. The ties are 7½ feet long, 2⅜ inches high, and weigh without ballast 99 pounds, when filled 160 to 170 pounds. The price is $32 to $34 per ton, or $1.44 to $1.50 a piece. As first class creosoted ties cost $1.40 to $1.50 in Germany, the iron ones are by far the most economical as their life is much longer. Except in wet tunnels where a crating of tar affords ample protection, oxidation is almost imperceptible on the outside and limited to a thin film on the inside. The wear under the rails is light, perhaps $\frac{1}{32}$ inches in 6 or 7 years, the breakage very small, being 172 ties out of 273,900 laid in the same time, the majority of which broke soon after laying, on account of improper fastenings. Derailment of course causes considerable damage.

This system is generally known as the Vamherni and is in use upon a number of roads in England, France and Germany. It is the only system which, in one or the other of its modifications, has found sufficient favor in the U. S. to be given a trial.

The use of simple tee irons for two has been suggested, but to secure stability so much iron is needed that the cost alone renders their use impossible.

We now come to longitudinal ties for which the following advantages are claimed:

a. A continued support of the rail and in consequence

b. Lessening of the cross section and weight of the rail to a minimum.

c. Strong reactions against a sidewise motion of the track.

The rail and longitudinal tie may consist of one, two or three parts; more, it has never been attempted to use.

As an example of the one piece system stands that of Mr. Harterich. It consists of a simple rail 8.25 inches high with a broad base which rests upon a thoroughly packed mass of ballast extending several feet beneath. Bars connect the opposite rails every 1½ feet to 5 feet. This arrangement was first proposed in 1865 and on account of its simplicity was extensively tried and found wanting. It forms a hard road bed and soon moves out of place. The minutes of the meeting of German engineers at Dusseldorf 1874, show that in the use of this system on account of the movement of the track safety is endangered, that the ends of the rails receive a permanent set, that the rails can be removed only with great difficulty when the ground is frozen, that the cost of maintenance is from 3 to 6 times that of any other kind of iron tie.

For the perfection of the two piece system are required the following conditions:

a. The rail must be of a hard material to resist the wear and shock.

b. The rail must have the smallest possible weight with great strength.

c. The rail must allow the use of a good system of connecting plates.

d. The rail must be easily turned over.

e. The long tie must be of light weight and have a great carrying moment.

f. The tie must be stiff against sidewise motion.

g. It must be deep enough to resist frost and shallow enough to allow easy tamping.

h. The tie must be easy to turn.

i. The ties must have a sufficient area.

k. The connection between the tie and the rail must be simple.

l. The cross connection must be simple and easily loosened and must be sufficiently stiff.

The design which best meets these requirements is that of Mr. Hilf, figs. 4, 5, and 6. The rail rests on a longitudinal tie and

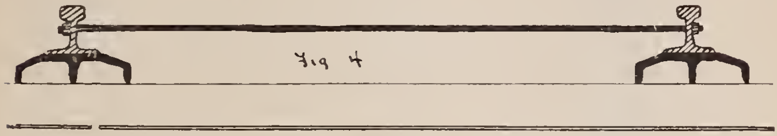


Fig 4

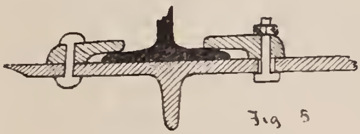


Fig 5

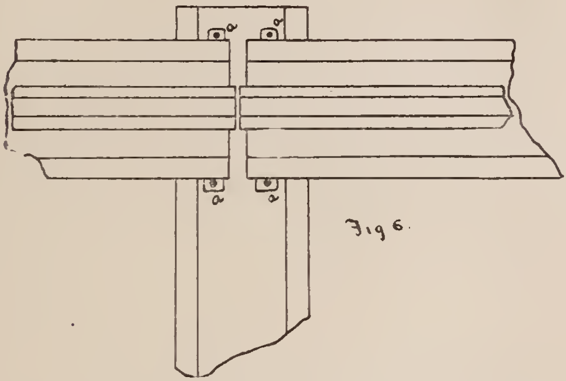


Fig 6.

this in turn at the joints rests upon cross ties of the same cross section. 9-meter rails are used. The longitudinal ties are from 8.96 to 8.86 meters in length, the variation is necessary to allow for curves, 300 mm. wide, 8 mm.thick and 2.6 meters long, weighing 29.37 kilos per meter. Small tie plates a. a. fig. 6 are inserted at the joints. The rail and tie are connected by 20 bolts and washers. On curves the bolt holes are punched to conform to the curve so that the bending of the rail is done gradually while fastening it to the tie. The punching is done at the shops. A crane is necessary to unload and load these ties and to help place them in position but when once laid they form a practically immovable roadbed. Generally two iron bars connect opposite rails for further stiffness. The Hilf design was first tried in 1867, was found durable, and gave a smooth roadbed. The main beauty of it is the almost mathematical accuracy with which it keeps in place. Despite the machinery necessary for putting it in position it was considered the best design in 1876 and was then in use on 14 German and Dutch roads.

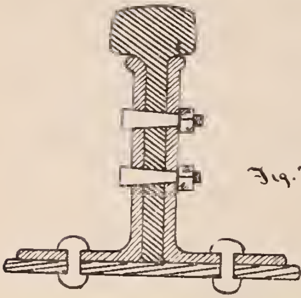


Fig. 7

Fig. 7 shows the principle of the three part system. It consists of a plate upon which are riveted two angle irons and between these fits a small rail which is fastened by bolts. It has no advantages of note and is particularly inconvenient because on curves all three parts have to be bent, a difficult thing to do with angle irons and flat plates. All trials on European roads and our own as well show that an entirely iron roadway has great advantages as regards safety and durability compared with wooden ties. What is still doubtful is whether ordinary cross ties or the system of Hilf is superior. The former are certainly preferable on new roads where the ground has not as yet settled and besides have the advantage of being easily handled, while the latter forms a solid, almost immovable roadway, which nevertheless is easily taken apart, but requires lifting machinery to handle it on account of its weight. F. E. Fisher.

PHOTOGRAPHIC SURVEYING.

READ BEFORE THE ENGINEERING SOCIETY.

Photographic Surveying, like scientific and experimental photography, has received little attention in this country, and owes its present development to those nations noted for their experimental work, France and Germany. Ever since the old wet plate days in photography, these investigators have been trying to make the camera do the work of the transit and level, and after much groping around among many methods and various interesting forms of instruments, they have given us a method of surveying with the camera itself. In fact, they have made the camera capable of doing the same work as the transit, including finding the declination, not with as much accuracy, it is true, but that is the fault of the instrument and not of the method. When the camera has reached the same perfection in construction as the transit, there is no reason why it should not do as accurate work. Photography has come into Surveying as it has come into other departments of scientific work, it has come to stay. And considering the extensive capabilities of the

instrument, it is surprising that its application to scientific work has not received more attention in technical and scientific schools.

At present, photography is applied to all forms of reconnaissance work In civil engineering it is used in making preliminary maps for rail-roads, plans and elevations of bridges and other engineering structures, maps of sections of country for miltary or purchasers use, maps illustrating peculiarities in geological formations, in fact, wherever speed in field work and not extreme accuracy are required, photography has done excellent work.

It is not within the limits of this paper to touch on all the instruments which have been devised to do photo-surveying work, so I will speak only of the camera, the one most easily procured and most universal in its uses.

A camera is essentially a lens, a dark chamber and a screen which can be replaced by a sensitive plate. The camera must be perfect—in the makers interpretation of the term—*i.e.*, the lens must be perfectly rectilinear and free from local distortion, the camera box must be light tight and provided with all the. movements except horizontal swing; beside these a small compass should be fixed to the top of the back, so that its N–S line is in the same vertical plane as the optic axis, and the front and back should be provided with small levels, to level them horizontally and vertically. It is an axiom in photography to "keep your back both plumb and level;" in surveying this applies to the entire instrument.

Moderately accurate instruments can be had of the principal dealers for from $75 upward. The running expenses will be about $2.00 for every small map, if a $5'' \times 8''$ plate is used.

After getting the instrument, the following adjustments are necessary.

1. Test for register, *i.e.*, to see whether the plate exactly replaces the ground glass screen. First focus accurately, expose and develop plate. If the image is sharply defined the register is all right.
2. To determine the equivalent focus of the lens, which is the perpendicular from the centre of the lens to the plate; It is approximately the same for all distant views, but should be recorded on the bed of the camera for different distances. The plate should be perpendicular to the

axis of the view, so that the axis passes through the centre of the horizon line. The method for making this adjustment can be found in any work on photography.

3. To find the horizon line, the line in which a horizontal plane through the centre of the lens cuts the plate, mark the projection of a point on the screen of the same elevation as the lens. A horizontal through this point will be the horizon line and may be permanently marked on the plate holder.
4. The angle of view of the lens is found by a few measurements and the solving of a triangle.
5. To test whether the lens is rectilinear, focus on a set of parallel lines whose image covers the screen. If they appear straight throughout, the lens is rectilinear and free from local distortion.

To include more of the view above or below, the lens must be moved up or down, the horizon line of course changing with it; this change should be put on a scale beside the lens and taken note of where the view is taken. It is the property of the photographic lens that the angle included between rays from two distant objects is the same after as before passing through the centre of the lens combination.

The negative should possess both density and detail, the latter being imperative. Slow plates are far better than fast plates for this class of work. Aristotype paper is the best for printing the pictures on, as it does not stretch and renders the detail well.

THE FIELD WORK.

The work in the field consists in setting up on the stations and taking views from left to right, or vice versa, making the views slightly overlap, so as to embrace the whole area, and taking the compass reading for every view. The precautions to be taken are to have the camera perfectly level and to look out for local attraction.

There are three methods of proceeding with field work:

1. When triangulation has previously been established, we can set up over the stations and include in the view at least one of the other stations from which the axis of the view can easily be found and the view oriented.

2. With camera and pocket compass. The direction of view is given by the attached compass, and thus the view can easily be oriented.
3. With camera alone.

Of these methods the first is the most accurate, but the second is the most applicable to reconnaisance work, so we will consider that alone.

Suppose we wished to make a map of the Lower Saucon district, East of the University.

We would first set up on *A* (fig. 1) on the side of South Mountain, after first measuring a base line between two prominent points along the creek, and expose on views including the part to be mapped; then we would go to *B* and do the same, repeating the operation at *C*, giving us a view of the district from three different points. This is all the field work to be done; the field notes are kept in the following form:

Station.	View No.	Slide No.	Bearing.	Horizon Scale.	Remarks.
A	1	3	S 20° 00′ E	0	
	2	5	S 75° 00′ E	+ 2.5	Contains B
	4	8	N 10° 00′ E	− 3.0	
B	1	2	N 25° 00′ W	0	Over exposed.

The horizon scale is the distance the horizon line has been moved above or below the centre of the plate by moving the lens up or down in getting into the field of view elevated or depressed objects.

This work would require about a half day for one man with an expenditure of a dozen plates and resulting in a map of 10 square miles, or more if desired.

PLOTTING.

The methods of plotting depend upon the following general principles.

The intersection of two lines determines a point; if a third line intersects in the same point it is accurately determined. So, if we know the directions of a point from two other points, we can map that point.

The direction of a line is determined when we know the angle it makes with a line whose direction is known.

Now, a map is the horizontal projection of certain points in the region mapped. If we pass a vertical plane through the axis of the view and another through the centre of the lens and a point in the view, the angle included by the intersection

of these planes with the horizon plane, will be the horizontal angle included between this point and the point where the axis pierces the view. Or, as the angle is the same after as before passing through the lens, this horizontal angle will be the same as that included between the axis of the view passing through the centre of the horizon line of the plate, and the line passing through the centre of the lens and the corresponding point in the picture. So that, if we draw the horizon line in the view, draw a perpendicular through the centre of it and also through the point, cutting the horizon line, and we measure this intercept, and also knowing the equivalent focus, we can easily solve the triangle and obtain the required angle.

Instead of calculating each angle, a device called the *tangent glass* is used, which will be decribed under finding the references. By making the horizon of the glass and the picture coincide, and also their middle verticle lines, the angle is at once seen by noticing which vertical line it coincides with. Fractions of degrees can be estimated to within six minutes or about 9 feet at the distance of a mile.

In plotting, first the *N–S* line is drawn and the position of

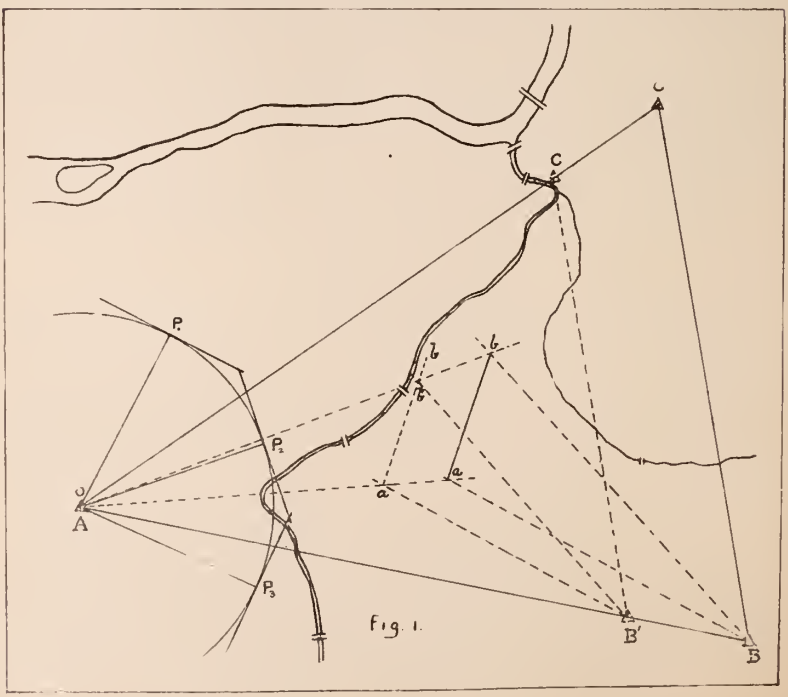


Fig. 1.

the station A chosen. Then with a radius $O\,P$, the equivalent focus of the lens, describe a circumference; draw OP_1, OP_2, OP_3, the axes of the views and draw tangents at P_1, P_2, P_3; these will be the horizon lines of the corresponding views. Project the points in the views upon their horizon lines and transfer to these tangents. Then points will lie on lines drawn through O and their projections. In this manner we find that B will lie upon AB' and C upon AC'. Assume B at B' and proceeding as at A, C' is located on the map and also the base line $a\,b'$ by the intersection of the direction lines. Laying off $a\,b$, the length of the base line reduced to scale, on $a\,b'$, we have a means of locating B; for $\frac{a\,b}{a\,b'} = \frac{A\,B}{AB'} = \frac{A\,C}{A\,C'}$ from which B and C are exactly located. Proceeding at B and C as at A, any point can be located by drawing lines through A, B, and C and its projection in the corresponding views. Directions from C serve as a check to the work.

It will be observed that the method is graphic, requiring no calculating. For greater exactness, the calculated angles are used, and the points found as before by intersection.

FINDING THE REFERENCE.

The elevations of points referred to their respective horizon lines can be found by one of three methods.

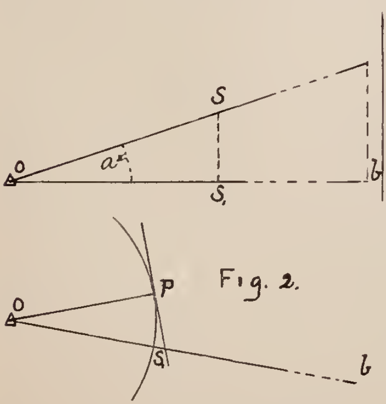


Fig. 2.

1. *Arithmetically.* Let s be a point and s_1 its projection on the horizon line $\tan a = \frac{S\,S_1}{O\,S_1}$ $o\,b\,\tan \alpha =$ the required height where b is the point in the map. This distance will be in the same scale as the map.

2. *Trigonometrically.* Let S be the point, $H\,H_1$ the horizon line, $V\,V_1$ the vertical, $O\,P$ the focal distance. Draw

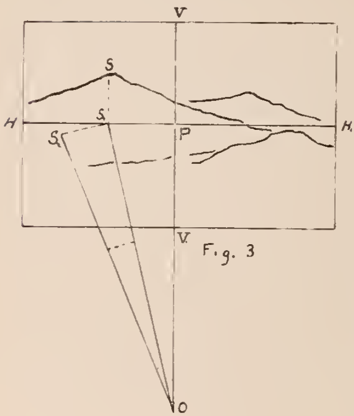


Fig. 3

$S\,S_1$ perpendicular to $H\,H_1$, $O\,S_1$ and $S_1\,S_2$ perpendicular to $O\,S_1$ and connect $O\,S_2$. With a protractor measure the angle $S_1\,O\,S_2$, the required angle. Measure the distance from O to S in the map, multiply by the tangent of the angle found and the product will be the elevation as before.

3. *Mechanically.* The vertical angle is most conveniently found by means of the *tangent glass* with the *vertical angle scale* attachment.

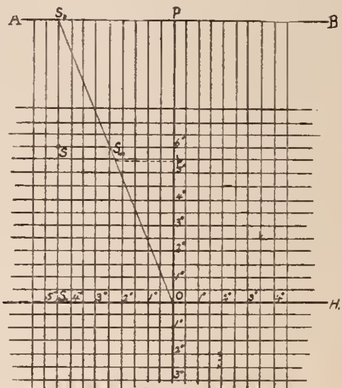
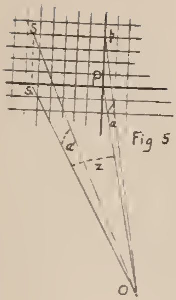


Fig. 4.

Part of such an instrument is shown in Fig. 4. $O\,P$ equals the focal distance. The vertical lines are produced until they meet $A\,B$ parallel to $H\,H_1$. $H\,H_1$ is the horizon line, $O\,P$ being the vertical through the middle. The natural tangents for radius $O\,P$ are computed for every half degree and degree from the tables and laid off on $H\,H_1$ and $O\,P$ from O, and parallel lines drawn through these points. These lines being etched on a glass plate or marked on some such transparent substance as ivory film or flexible-film, and placed on the picture with their horizon and vertical lines coinciding will evidently give the angle at once for the horizontal plane. For the vertical angles however, the attachment must be used. Suppose S to be a point in the picture, whose elevation is required; S_1 will be its projection on the horizontal line and S_{11} on $A\,B$. On $O\,S_{11}$ lay off $OS_{111} = S\,S_1$; draw $S_{111}\,P$; then $O\,P$ is the tangent of the vertical angle required. For

$$\cos z = \frac{O\,P}{O\,S_{111}} \qquad O\,P = OS_{111} \times \cos Z\,O\,P = O\,P \tan \alpha' \qquad O\,S_{111}$$

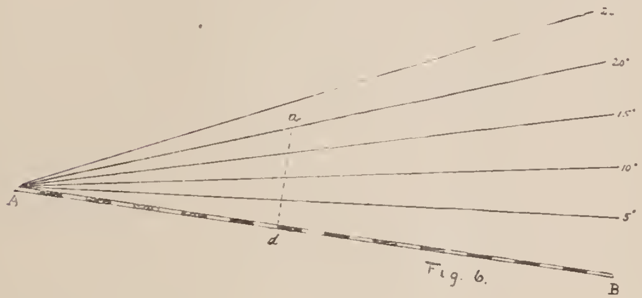
$= O\,P \tan \alpha^1$: substituting we have $\tan A' = \tan A \cos Z$. To show more clearly that this is the required angle A', take Fig. 5 with the same nomenclature as before.



$$\tan a' = \frac{Pp}{OP} \quad \tan a' = \frac{SS_1}{OS_1} \quad OS_1 = \frac{OP}{\cos Z}$$

A B is drawn to the same scale as the map; the radial lines are drawn making angles with *A B* of 30′ intervals, or less.

Suppose the point *s* was situated 2200 feet from *A* on the map, having a verticle angle of 20°. On the scale *A B*, at the 2200 foot division, *d*, erect a perdendicular to the 20° radial. Then will *a d* be the required elevation



which being multiplied by the scale will give the elevation in feet. Greater exactness may be obtained by doubling the scale. In these graphical methods considerable care is necessary, in connection with a magnifying glass and accurate instruments in order to get the best results. As in other methods of surveying, the sources of error should be reduced to a minimum.

Having the reference of each view referred to its own datum line by means of the reference of the station as found in the other views, the following is the form used for the purpose:

View.	Point.	Reference.	Reference of Station.	Final Reference.	Remarks.
A	1	102	460	562	Top of bluff.
	2	90		550	Pine tree on hill.
	3	–25		435	Creek at iron bridge.
	4				

When we have the elevation of all points it is a simple matter to put in the contours. A little practice will enable one to so select the points that they will be near the contour lines.

ADVANTAGES.

In some classes of work or emergencies it is necessary that a tolerably accurate map should be made in a very limited time in

the field. The map of a region affected by a flood, or of an extensive wash-out, or dangerous ice-pack, or a map for the estimation of damages which could not be made within a couple days having several men employed with instrument, could be made complete in less than one day by one man and camera, for the negative is often used instead of the print. The map in connection with the pictures conveys all the information that is generally required, outside of statistics. Of course it can only be used where there is a clear field of view and is not so accurate as the transit and level.

The extent included by the view is another advantage. Prints anywhere within range of vision can be mapped and the relative position of the mapped part clearly shown.

Again, *all* visible points can be mapped, so that the picture is a permanent record of both the mapped and unmapped points.

This is especially valuable in case of objects not fixed which may give rise to a dispute by their removal. A photograph can not be disputed, and would settle the point at once. Prints sent to the head engineers office with the field notes on the back would form a decidedly valuable series of reports, which could be consulted with ease at any time and innumerable copies be quickly made.

As evidence in courts, a photographic picture of this kind could not have its evidence doubted. An expert could tell at once whether there had been any trickery in the making of the negative, for the negative only should be presented, and thus make the negative both in name and reality a truthful witness.

H. K. Landis.

EDITORIALS.

A FIRST number of a new volume of the JOURNAL is again submitted to the attention of our readers, and a few words *apropos* to the occasion may not be entirely out of place.

We have often thought that the precise mission of the JOURNAL has never been fully understood by our undergraduate and other readers. In literary institutions it is customary to publish at suitable intervals a literary magazine containing the best and soberest thoughts of which the undergraduate mind is capable. It is therefore appropriate that at technical institutions a similar publication should be issued, technical in its character, containing contributions exponential of the effect that the university work exerts upon the minds of its contributors.

We should like right here to emphatically assure our readers that this is the precise field this publication desires to fill. It is decidedly opposed to narrowness and exclusiveness. It is published in the interests of no one particular class or course. Articles of a scientific nature showing the proper amount of thought and accuracy will be published on any subject.

The columns of the JOURNAL will not be open to undergraduate contributors exclusive of all others. On the contrary we earnestly solicit articles from our alumni. These will tend to give it an interest it certainly would not otherwise possess, and render it more readable and authoritative not only to our undergraduates but the alumni and friends of the University at large.

For the benefit of those who may be disposed to criticize too harshly the work done by our younger contributors we cannot refrain from repeating the story told by Boccalini.

Zoilus once presented Apollo with a very caustic criticism upon a book, whereupon Apollo asked him for the beauties of the work. He replied that he only concerned himself about the errors. On hearing this Apollo presented him with a sack of unwinnowed wheat, and commanded him to pick out all the chaff for his reward.

In other words we request our more learned readers to overlook mistakes that will undoubtedly occur, and search rather for the truths demonstrated. We maintain that while a man may not write his best while he is an underclassman, or before he

leaves college, yet the best possibilies will certainly not be realized in this direction after his graduation, without the aid of former practice, and we feel that the members of the Engineering Society and others cannot be urged too strongly to show in the future more enthusiasm in this work than they have evinced in the past.

It gives us a great deal of pleasure to print in this issue an article written by Prof. Klein. The bearing of the laws of the "Deformation of Materials" on practical and technical subjects is of great importance. We believe that this is the first time the discussion has been ventilated in the English language. From all concerned in the welfare of the Journal and the Engineering Society thanks are due to Prof. Klein for the interest he has manifested.

G. F. Duck, '83, Instructor in Mining, has been appointed Dean of the Faculty of the South Dakota School of Mines, at Rapid City, South Dakota.

Mr. Duck has had extensive experience in the mines of the South, and in the anthracite and bituminous regions of Pennsylvania. During late years as instructor in his specialty in this University he has met with marked success. The Journal, of which he was an editor last year, voices the sentiment of the Engineering Society, and his friends in college at large in wishing him all possible success in his new departure.

ALUMNI NOTES.

1876.

—Robert W. Mahon, C.E., (Ph.D., Johns Hopkins,) 316 N. Exeter Street, Baltimore, Md.

1882.

—Elmer H. Lawall, C.E., Superintendent Coal Department, New York, Susquehanna & Western Railroad Company, Scranton, Pa.

1883.

—Henry A. Butler, B.S., with M. S. Kemmerer, Mauch Chunk, Pa.

—John Ruddle, M.E., General Supervisor, Canal Department, The Lehigh Coal and Navigation Company, Mauch Chunk, Pa.

1885.

—Clarence M. Tolman, M.E., Railway Department, Northwest Electric Construction and Supply Company, 403 and 405 Sibley Street, St. Paul, Minn.

1886.

—Charles A. Junken, C.E., Hydrographic Office, Washington, D. C.

—Charles A. Luckenbach, B.M., Clerk of Police Courts, 121 Carroll Ave., Angelino Heights, Los Angeles, Cal.

—William H. Sayre, Jr., M.E., McDonald & Sayre, Railroad Contractors. Address: South Bethlehem, Pa.

—Theodore Stevens, B.M., E.M., Assistant Superintendent, the Metal Reduction Syndicate of London, Patricroft, Lancashire, England.

—Curtis H. Veeder, M.E., Draughtsman, Thomson-Houston Electric Co., 620 Atlantic Ave., Boston, Mass. Address: 113 Franklin Street, Lynn, Mass.

1887.

—Henry B. C. Nitze, E.M., with Phillips & Claghorn, Engineers, Chemists and Assayers, 2014 Morris Ave., (P.O. Drawer 848,) Birmingham, Ala.

—W. Hampton Woods, B.S., B.M., E.M., Chemist, The Empire Zinc Co., Joplin, Mo.

—George F. Yost, M.E., Draughtsman, Brass Foundry & Machine Works, Fort Wayne, Ind.

1888.

—William Gates, Jr., C.E., Engineer Corps, Philadelphia & Reading R.R., 705 N. Eleventh Street, Reading, Pa.

1889.

—Pearce Atkinson, M.E., Railway Supplies, care of G. W. P. Atkinson, Chicago, Ill.

—Albert H. Bates, M.E., Law Student with Watson & Thurston, Patent Lawyers, 22 Wilshire Building, Cleveland, O.

—Samuel E. Berger, B.A., Instructor in Latin, Central High School, S. E. cor. Broad and Green Streets, Philadelphia, Pa.

—Joseph L. Budd, A.C., Chemist, Edgar Thompson Steel Works, Braddock, Pa.

—Francis J. Carman, A.C., Chemist, Emery Manufacturing Company, 41 Main Street, Bradford, Pa.

—Charles W. Corbin, B.S., Telluride, San Miguel County, Col.

—Emil Diebitsh, C.E., Computer, Massachusetts Town Boundary Survey, 807 T Street, N.W., Washington, D. C.

—Ralph M. Dravo, B.S., 132 Western Ave., Allegheny, Pa.

—William D. Farwell, B.A., Editorial Rooms, New York *Tribune*, Tribune Building, New York City.

—Archibald Johnston, M.E., 335 Broad Street, Bethlehem, Pa.

—John Lockett, M.E., Mechanical Engineer, Kaolin Chemical Company, 31st Street and Gray's Ferry Road, Philadelphia, Pa.

—Arthur Long, A.C., Denver, Col.

—Charles H. Miller, A.C., 112 E. Main Street, Norristown, Pa.

—Charles W. Moffett, M.E., care of W. H. Moffett, U. S. Consulate, Athens, Greece.

—Albert D. Oberly, C.E., Engineer Corps, H. C. Frick Coke Company, Scottdale, Pa.

—Joseph M. O'Malley, A.C., Wilkes-Barre, Pa.